SCIENCE EDUCATION TOOLKIT

EXTRAORDINARY PREDICTIONS REQUIRE EXTRAORDINARY EVIDENCE

LUMINOUS

A Film by Sam Smartt

TOOLKIT CREATED BY THE UNIVERSITY OF CALIFORNIA MUSEUM OF PALEONTOLOGY AT UC BERKELEY

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& Overview

About the Film

LUMINOUS tells the story of astronomer Larry Molnar as he investigates a distant, double-star system, about which he makes a daring and explosive prediction. Interviews with Dr. Molnar's diverse set of colleagues, collaborators, and skeptics highlight science as a community and intensely human endeavor, debunking the myth of the lone scientist conducting dispassionate research. Instead, we see how Dr. Molnar's deep Christian faith motivates his work, and we follow the team as they experience joy, disappointment, and frustration, facing their doubts and overcoming setbacks. Their journey highlights science as a messy, dynamic, and exciting process of trying to understand what we observe in the universe, where being wrong can inspire new explorations and teach us just as much as being right.

How Can I Watch LUMINOUS?

LUMINOUS is available for educational and community-based screenings and for college & university classrooms. For more information about accessing the full film and to download engagement materials, please visit: LUMINOUS-FILM.COM/SCREENINGS

Letter from the Filmmaker

It was a sunny Sunday afternoon in November several years ago that I first heard about Larry Molnar and his potentially groundbreaking discovery. I was sitting across my kitchen table from the chair of his department, Matt Walhout, listening to him talk about exploding stars and drop phrases like "first time in the history of science" and "could be in most astronomy textbooks." And while I confess that I was drawn in by the prospect of a "big" story, I was most intrigued by the uncertainty inherent in the prediction and in its unlikely source.

The essential ingredients in any good story are conflict and tension. If I waited to pick up the camera until I found out whether Larry was right, the story wouldn't be interesting anymore. Who would appreciate the audacity of an unknown astronomer from a small midwestern college making such a bold prediction if they didn't feel the stakes? As a filmmaker, I needed to make the audience buy into the journey Larry was embarking on, with all its inherent risks.

I've learned a lot over the nearly eight years that have passed since that afternoon in November, but two things stand out. The first is that science stories are human stories. I often prefer to describe **LUMINOUS** not as a traditional science documentary, but rather as a personal journey film set against the backdrop of scientific discovery. We often think about science as a set of facts easily and inevitably mined by lab coats following a set scientific "method" rather than as a complex process undertaken by real people with hopes and fears, tragedies and failures, passions and—in Larry's case—faith.

Second, I learned that the filmmaking journey mirrors the scientist's journey. Making a feature documentary also involves risk, especially a longitudinal project in which you follow a story you cannot control to see how it develops over many years. Like the scientist, you must show up without preconceived notions of what will happen. You must have the stamina and tenacity to gather your "data" over long stretches of time, despite obstacles, and the problem-solving acumen to figure out what story that data is telling you. Most importantly, you must come to the project with an openness to follow your evidence wherever it leads.

Before I started making **LUMINOUS**, I really had no idea how pervasive our societal misconceptions of science are, and I've realized that one contributing factor is how people like me have told science stories in the past. We tend to focus on the high-profile successes, the multi-billion-dollar international collaborations, the pinnacles of human achievement. These certainly deserve to be celebrated, but they are the safe stories. They do not jibe with the daily lived experience of the millions of scientists who go to work each day and over many years contribute incrementally to human knowledge, more often through their setbacks than their triumphs.

In filmmaking, as in science, the real steps forward can only be made when we are willing to take risks. I've become convinced over the last eight years that, for this reason, stories like **LUMINOUS** are more important now than they ever have been. I hope you enjoy this journey, and that you learn as much from it as I have.

SAM SMARTT
Director & Producer

How to use this guide

This guide was created to support the use of the film **LUMINOUS** by college instructors and campus leaders to catalyze rich student explorations and discussions about the nature and process of science. The resources in the guide are appropriate for a general undergraduate student audience and various courses, including science (especially astronomy, physics, and Earth sciences), philosophy of science, epistemology, religious studies, science methods, and various education classes.

The guide has four sections:

01 **INTRODUCTION** frames the context of the film and guidance for users.

02 **VIEWING THE FILM** provides pre- and post-viewing discussion and essay questions. Instructors and event leaders should select the questions that are appropriate for their students or participants.

03 **ACTIVITIES FOR EXPLORING THE NATURE AND PROCESS OF SCIENCE** includes step-by-step instructions for engaging students in the classroom and homework assignments that provide opportunities for learners to interact and share ideas about what they viewed in the film. Each activity can be used individually or in combination with the other two in any sequence, depending on your instructional goals, and are adaptable for informal community events. The film could be viewed as homework to preserve classroom time for small group and whole class discussions, which is important for student sensemaking and developing an understanding of the concepts explored in the film.

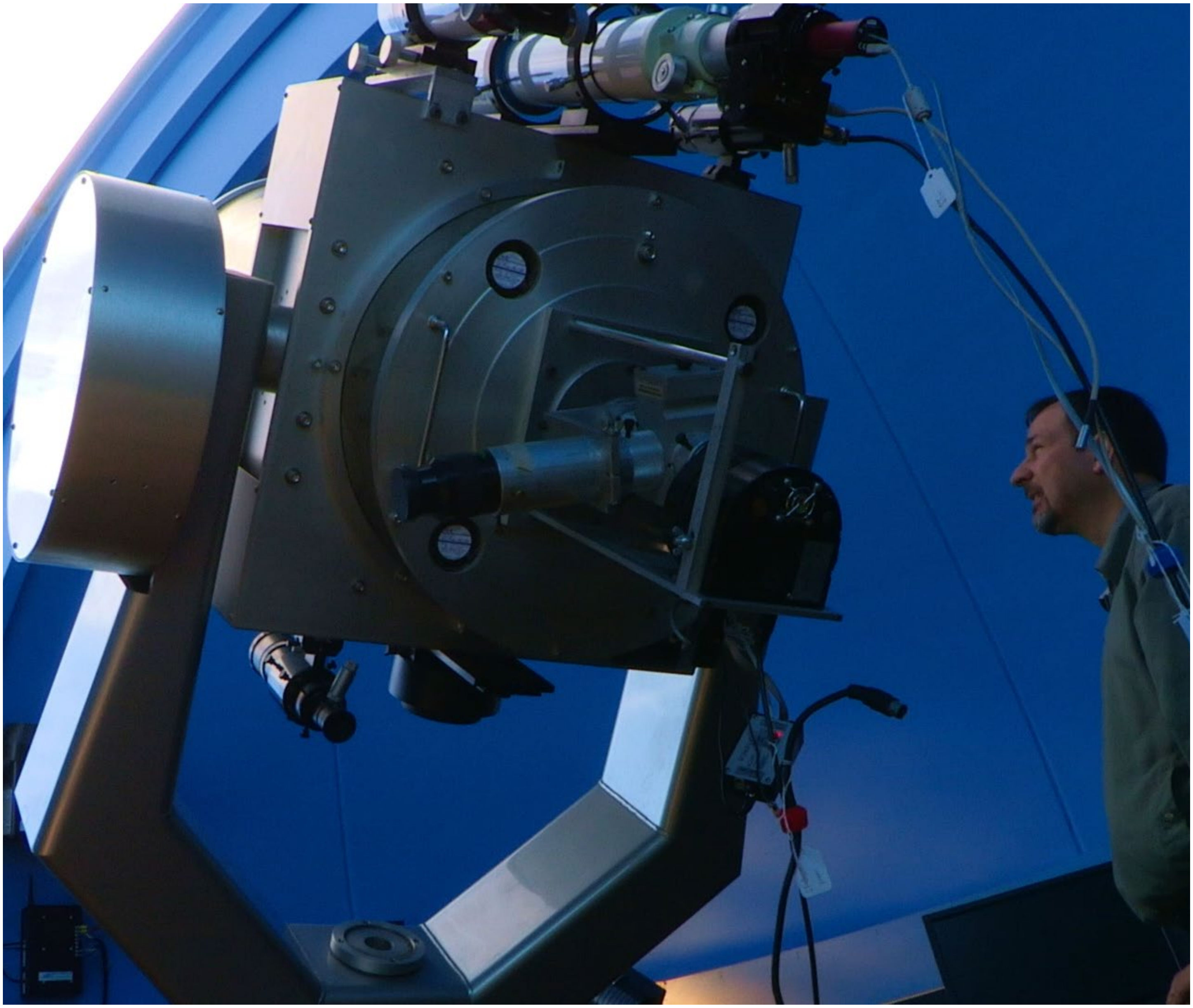
04 **ADDITIONAL RESOURCES** provide links to learn more about teaching the nature and process of science.


02
Viewing the Film

Pre-viewing Questions

Use these questions to help students start thinking about the concepts and ideas explored in the film LUMINOUS.

1. What does it mean to engage in the process of science?
2. What are your thoughts about who scientists are, where they work, and what characteristics they share with each other?
3. What do you think about when you hear the phrase “scientific community”?
4. What does it mean to “succeed” or “fail” when doing science? Is failure always bad?
5. Can someone be a scientist or behave scientifically in their daily lives while also holding religious or spiritual beliefs? Why or why not?



Post-viewing Questions

Use these questions to help students reflect on how the themes and concepts in the film **LUMINOUS** are connected to your own life, experiences, and ideas about science.

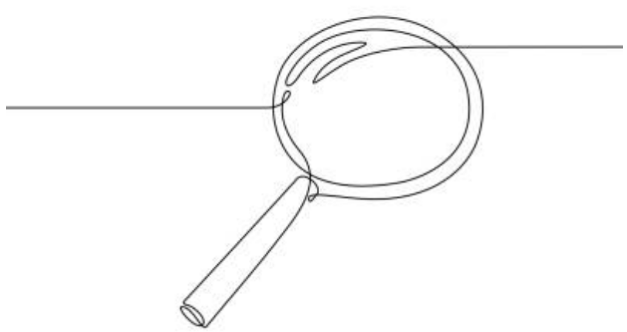
1. Did watching Dr. Molnar and team's story change your perception of science and/or of who does science? Explain.

2. What role did the scientific community play in Dr. Molnar and team's work? Why is the larger scientific community important to the process of science?

3. Explain why you agree or disagree with the following statement: Scientists contribute to our understanding of how the natural world works even when their initial hypotheses are incorrect.

4. In the film, we get to know Dr. Molnar as a "whole" person – a scientist, family member, and active community participant. Pick three people that Dr. Molnar interacts with in the film and describe how these people are connected to his professional life, personal life, or both. Now think about your own life as a student and beyond the classroom, and explain how three people have shaped your personal and/or professional life.

5. Has Dr. Molnar's story changed your ideas about whether someone can work as a scientist and hold religious or spiritual beliefs? Why or why not?



Essay Questions

These questions can be assigned to students as the topic for essay or research projects depending on your instructional goals.

1. Scientific knowledge is simultaneously reliable and subject to change, traits which are sometimes perceived to be in tension with one another. What aspects of the nature and process of science cause the knowledge it generates to be reliable? What aspects of the nature and process of science cause the knowledge it generates to be tentative? How do you see both of these traits of scientific knowledge exemplified in Larry Molnar's journey? In what ways can these traits (reliability and tentativity) be exaggerated or incorrectly interpreted when scientific findings are communicated to the broader public? Use examples of socioscientific issues – societal concerns that are informed by scientific knowledge and evidence – and the varying public reactions to them to illustrate your points.

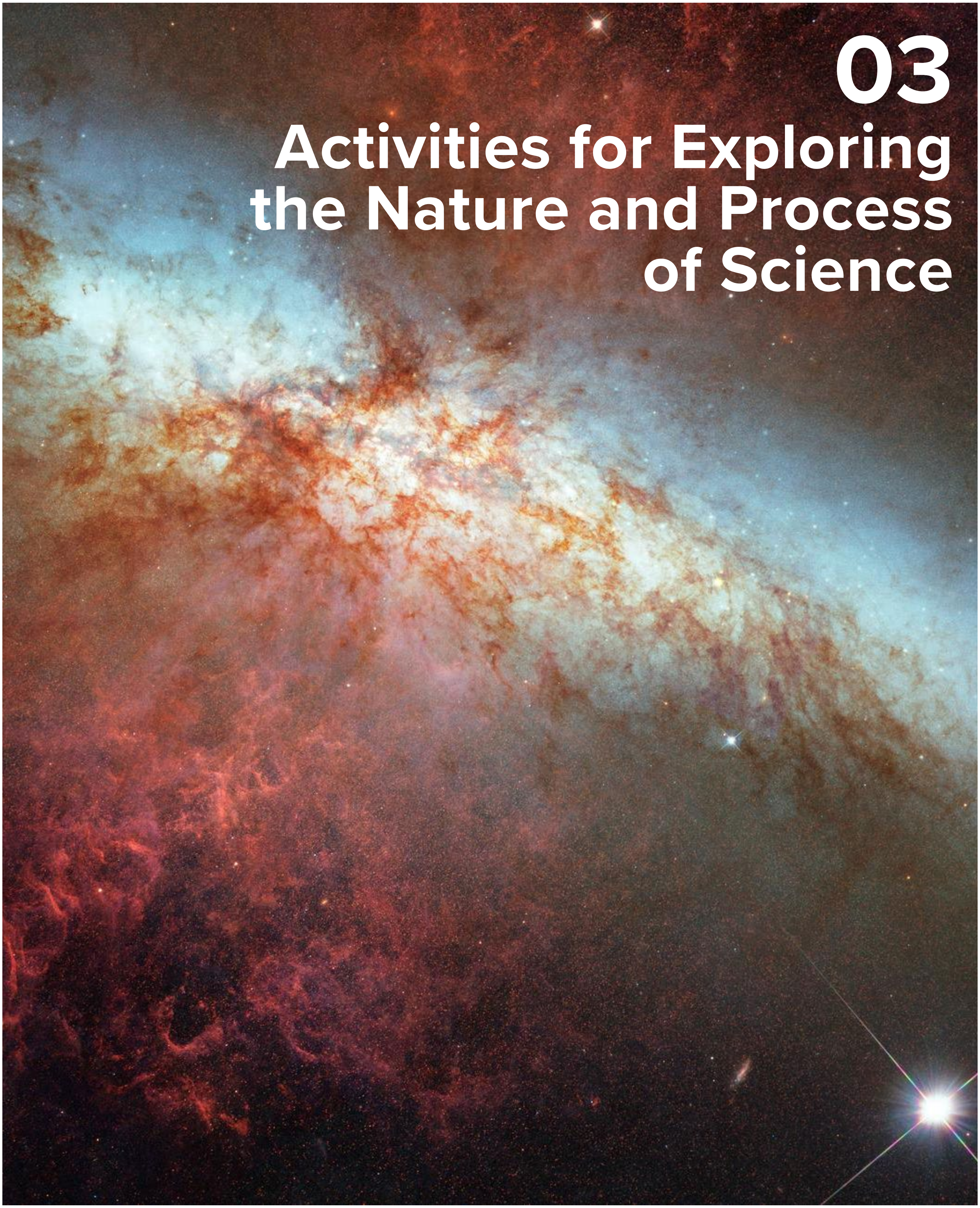
2. Scientific pursuits are commonly (and falsely) idealized as "pure" – that is, pursued to build knowledge alone, conducted and evaluated in fully objective and impartial ways, and uninfluenced by the personal traits, backgrounds, and beliefs of individual scientists. In what ways does the film illustrate the fallacy of this misconception? Use examples from other scientific disciplines to further illustrate these points. Explain how you see this lack of "purity" – i.e., the fact that science is a human endeavor, shaped by the diverse and fallible humans that pursue it – affecting the course of science and the knowledge that it builds. Is it a strength, weakness, or neither? Explain your perspective. How can science get past the personal biases of scientists in order to build accurate knowledge about the world?

3. In the film, Mark Reid, Dr. Molnar's Ph.D. advisor at Harvard states, "Larry was, I thought, unbelievably smart, meticulous, and already an excellent scientist when he came here. It's sort of something, I think, you almost can't teach somebody, is how to be a really good scientist." Reflect on this statement using examples and/or counterexamples from the film and from your own life. What skills used in scientific research might be more or less amenable to instruction? Are there traits or skills that are essential for all scientists to have and can these be taught?

4. Research has established that many students hold stereotyped views of scientists' identities and traits. In what ways do the many scientists who appear in the film fit and/or refute these common stereotypes? Be sure to include consideration of factors and traits beyond racial background and gender identity. How do you see these stereotypical and non-stereotypical traits affecting the course of the research presented in the film? How would you expect the diversity (or lack of diversity) of its participants to impact science more broadly? Explain your reasoning.

5. Throughout the film, skepticism and scrutiny are applied and reapplied to ideas about and data on variable stars. Describe the range of ways that skepticism and scrutiny factor into the journey of Dr. Molnar and team. More broadly, what is the role of skepticism in the process of science and how does it shape the development of scientific knowledge?

03 Activities for Exploring the Nature and Process of Science



How Science Really Works

TIMING: 3-4 hours total (Recommendation: At least 1.5 hour of class time over two days, potentially 2 hours outside of class)

OBJECTIVES
Students will:

- Create their own models of the process of science based on their prior knowledge.
- Become familiar with a non-linear, iterative model of the process of science, the How Science Works Flowchart.
- Map the aspects of science they observe in the film on the How Science Works Flowchart.

MATERIALS

- Access to the film
- Blank paper for students to take notes
- Poster paper for each group of 3-4 students
- Markers
- For online learning or one-to-one computing environments, use a blank Jamboard instead of poster paper and markers
- Access to the *How Science Works* Interactive and additional *slide instructions*
- Handouts of the *"How Science Works" flowchart*, one copy for each student (optional, but recommended). Various versions of the flowchart are available on the UC Berkeley *Understanding Science website*.

Overview
Students create a model of their understanding of the process of science, are introduced to the How Science Works Flowchart, watch **LUMINOUS**, and then discuss the aspects of the scientific process they observe in the film.

TEACHING TIP

Students are likely familiar with "The Scientific Method" and we will use that prior knowledge to further their thinking about how science really works.

Teaching Tips

- Students are less likely to include discussions with peers, presenting their ideas, or communicating science in their communities in their models than other parts of the process of science, such as asking questions, or collecting data. However, activities within the scientific community and increasing public understanding of science are important parts of what it means to do science. Students will observe the scientists in the film engage in these activities.

- If you are doing this activity online, students can use Jamboard to collaboratively build their initial models of the process of science. We recommend dividing students into breakout rooms and providing each group with their own page on the Jamboard. The teacher can see all the activity on the Jamboards as students work and you can save Jamboards as images or PDFs.

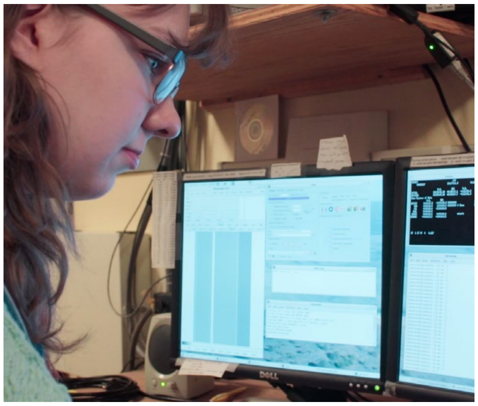
- Instructors should become familiar with the "How Science Works" flowchart and interactive before class.

- There are two versions of the "How Science Works" flowchart in the Interactive: "Detailed" and "Basic." Please review the versions and determine which one is most appropriate for your students. The "Detailed" flowchart is recommended for students in high school and college, while the "Basic" flowchart is usually recommended for students in middle school or younger. Note that the "Basic" model has fewer components and more accessible language, but the "Detailed" model offers more components to describe the processes of science.

- Students should have an opportunity to compare their own ideas about the nature and process of science to the elements in the "How Science Works" flowchart. This is an important step to help learners realize what aspects of the flowchart they already identified in their own models and become familiar with the new language and ideas in the flowchart.

- Students will likely recognize that the "How Science Works" flowchart more accurately and completely describes the nature and process of science than their initial models but will need guidance in recognizing that science can "start" in many ways, and never really ends because the work continues within the larger scientific community

- The film is approximately 1.5 hours long and could be viewed as a homework assignment.



Procedure

PART 01: PRE-VIEWING DISCUSSION, WRITING, AND DRAWING, PLUS ASSIGNMENT (55 MINUTES IN CLASS, ~2 HOURS OUTSIDE OF CLASS)

1. Ask students: How does science work? What are the parts of the process of science? Have students silently answer the questions on their own papers (5 min).

2. Next, have students work in groups of 3-4 to draw a model that represents their ideas about the process of science (10 min). For classroom instruction, models can be created on poster paper. For distance learning, students can work in groups in breakout rooms to make a model in Jamboard. Additional instructions:
   - Use arrows, words, and drawings to communicate your ideas.
   - There are no wrong answers!
   - Each group member should use a different color pen or stickies so everyone's contributions can be seen. Note: Jamboard work is anonymous, so this can help you track student participation.
   - Be prepared to share your model in a gallery walk with the rest of the class!

3. Students should have an opportunity to view the models created by other groups during a Gallery Walk (10 min). Tell students to view the other group models and think about:
   - What are the similarities and differences among the information on the models?
   - Are there components of their models they want to add, remove, or modify based on what they see on the other models?
   - Use green (or whatever color you decide for your class) stickies to leave at least two comments or questions for other groups. Comments should help to move the explanations forward – not just say "good job" or "I disagree."
   - Optional: Ask them to please put their initials on their comments so everyone knows they contributed! Note: Jamboard work is anonymous, so this can help you track student participation.

4. Now lead a discussion about the key concepts that all the models contain (10 min). Take notes on the board as students talk, ask students to build on each other's ideas, and group similar ideas together. For example, after a student shares an idea, ask the class, "Does anyone want to add anything to that idea?" or "Have we heard a similar idea we can group that with?" As students share, try to guide them to talk about ideas that represent the four primary categories in the "How Science Works" flowchart:
   - Testing Ideas
   - Exploration and Discovery
   - Community Analysis and Feedback
   - Benefits and Outcomes

5. After students have discussed their ideas as a class, introduce the simple version of the diagram. Explain to students that this diagram was developed by a team of scientists and educators at UC Berkeley to represent the complexity of how science really works. Ask students to compare the How Science Works Flowchart to an example of "The Scientific Method" (such as UNDSCI.BERKELEY.EDU/ARTICLE/0_0_0/HOWSCIENCEWORKS_01) to note the similarities and differences.

6. Next, go through the introduction to the "How Science Works" flowchart (either "Detailed" or "Basic" version) in the online interactive. Click: BIOINTERACTIVE.ORG/CLASSROOM-RESOURCES/HOW-SCIENCE-WORKS and either launch the browser version or download a desktop version (macOS or Windows). Once the interactive is open, you can select either "Detailed" or "Basic" (note: "Detailed" is the default setting). Then Click "Intro" to start the introduction.

7. Read through the introduction with your students and click through the frames using the arrow on the bottom left of the screen. Alternatively, students could read the introduction by themselves, and then you could discuss any questions they have about the introduction as a group.

8. Demonstrate how the interactive works by watching the first five minutes of the film with your students and then start mapping Dr. Molnar's story onto the flowchart. Students might not all agree where to start, and it's OK for students to have different interpretations of the film, but try to identify 2-3 of the concepts in the flowchart that are explored at the beginning of the film.

9. Now students will use the "How Science Works" flowchart to track Dr. Molnar's path through the scientific process as they watch **LUMINOUS**. Students should explain each step in the path they draw on the flowchart. Let students know that the order of the steps is not as important as documenting the various ways that Dr. Molnar engaged in science. Additionally, there are many different pathways to document his journey, and students' diagrams will likely look different from one another. The film could be viewed as homework and documenting his path could be finished as homework. There are three ways to engage students in mapping Dr. Molnar's scientific process:
   - Using the "How Science Works" Interactive, students can save their work as a zip file and export their work into a PowerPoint file. Step-by-step instructions for how to use the interactive are provided here.
   - Working on a Jamboard or Google Slide that contains

an image of the Flowchart to digitally draw Molnar's pathway through the process of science and annotate the steps with text boxes.

- Using a paper copy of the "How Science Works" flowchart to document Dr. Molnar's process.

PART 2: POST-VIEWING DISCUSSION (15-30 MINUTES IN CLASS)

1. Post viewing: After students document Dr. Molnar's process, have them pair up or combine groups to compare their responses. No two maps are likely to be exactly the same since students may interpret some of the language in the flowchart differently or emphasize different ideas about how the research proceeded. This is fine and expected since the film does not include footage of every part of his journey. However, students should explain each of the steps in their flowchart. Remind students that the "How Science Works" flowchart is a tool they can also use to reflect on their own scientific experiences.

2. Ask students to reflect on what they learned about this new model of the process of science. Students could work in groups or talk as a class about the following questions:
   - Is there anything surprising about this model of the process of science?
   - How is this model different from the model your group constructed? How have your ideas about the process of science changed ?
   - Is there just one place to start engaging in the scientific process? To finish the process? Explain.
   - What do the arrows in the flowchart communicate about the nature of science?
   - Why do you think Testing Ideas is at the center of the diagram?

Is it Science?

Overview

Students watch the film **LUMINOUS** while identifying the key features of scientific endeavors in the protagonists' journey. Students then complete a small group research assignment to identify these same features in other contexts. In Philosophy of Science courses, this activity can be paired with discussions and readings on how to distinguish science from non-science (the demarcation problem).

TIMING: 1.5-2 hours in class, and 3-4 hours of student work outside of class

OBJECTIVES

Students will:

- Understand the key features that distinguish science from other sorts of endeavors.
- Recognize these features in the journey of Larry Molnar and colleagues.
- Analyze an activity to identify what behaviors, practices, and traits align with those of scientific research and which differ.

MATERIALS

- *Science Checklist* slide
- *Science Checklist* worksheet
- *Is It Science?* handout

Procedure

PART 01: PRE-VIEWING DISCUSSION AND WRITING (30 MINUTES)

1. Share with students that they will be analyzing the question of how to define and recognize science. Ask the class to come up with five examples of endeavors that are definitely examples of people engaging in science and five examples of people doing something that is definitely not science. Keep running lists of these ideas on a board or screen. You might seed the discussion with the examples of "studying how to best treat cancer" and "painting a picture." Help the class come to agreement on lists that all the students feel confident about.

2. Give students five minutes of solo-writing time to list the traits that they think the scientific endeavors have and the non-scientific endeavors lack. To get them started, you might give an example of something like "involves gathering evidence." Some students might use the word "inquiry" in their list, which is used to describe learning and exploration in various disciplines, so students should be pressed to think about how scientific inquiry is different from other forms of inquiry.

3. Lead a discussion about their ideas, assembling an inclusive list of the features they identify.

4. Ask students to select the three they think are the most important features of science. Take a poll to identify the consensus features deemed most important.

5. Introduce the Science Checklist on this slide. Explain that, as they've just demonstrated, there is not a single easy way to distinguish science from non-science. Instead scientific endeavors tend to have a cluster of characteristics, summarized in this checklist. Identify the traits on the Checklist that they also identified as important features of science in the previous step.

6. Go through the items on the Checklist and, for each, ask the class to reflect back on the endeavors they identified as clear examples of science in step 3 and explain how it might embody that feature. Note on the slide a key point for each Checklist item. A few points are likely to require additional clarification:
   - The meaning of the word "natural": Within science, the term natural refers to any element of the physical universe — whether made by humans or not. This includes matter, the forces that act on matter, energy, the constituents of the biological world, humans, human society, and the products of that society. For more, see What's natural?
   - What is "scientific behavior": These are ways of behaving that help science construct accurate explanations of the natural world. Scientific behaviors include learning about work in one's field that others have done, exposing one's ideas to testing, assimilating new evidence, and openly communicating ideas and evidence to others. For more, see Participants in science behave scientifically.

PART 02: VIEWING AND WORKSHEET ANNOTATION (2 HOURS OUTSIDE OF CLASS)

1. Distribute the *Science Checklist* worksheet, or share it as a Google doc.

2. Assign students to watch the film **LUMINOUS** (in class or as homework) and annotate the Science Checklist worksheet. For each item on the Checklist, students should write 1-3 sentences explaining how the journey of Larry Molnar and colleagues illustrates that aspect of scientific endeavors, using specific examples from the film.

PART 03: POST-VIEWING DISCUSSION (15 MINUTES IN CLASS)

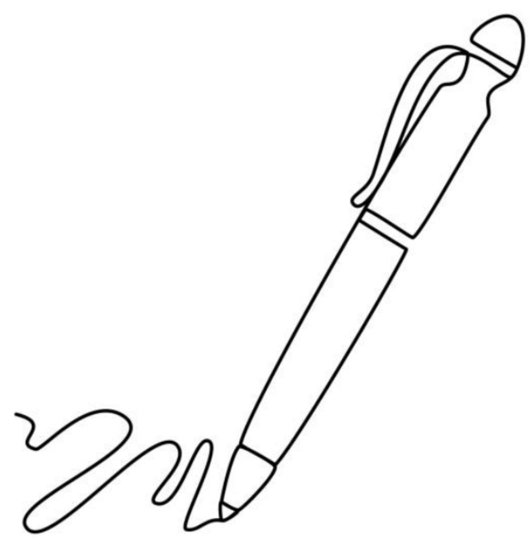
1. Lead a class discussion based on the prompt "Based on what you observed in the film, does Larry Molnar and colleagues' investigation of the potentially collapsing binary star system have the characteristics of scientific research?" Be sure to address the question of whether this assessment is impacted by the fact that the team's central hypothesis turned out to be incorrect. Be sure to ask students if anything about Larry's journey conflicted with their ideas of what science is or how scientists behave within or outside of the scientific community.

2. Solicit students ideas about whether some items on the Checklist might be more important than others. Help students recognize that the first four items on the Checklist outline what sort of knowledge science builds and how it is built (the epistemology of science). The last three traits, on the other hand, allow scientific endeavors to more efficiently and accurately build that knowledge.

PART 04: SMALL GROUP ASSIGNMENT (1-2 HOURS OUTSIDE OF CLASS, PLUS TIME FOR IN-CLASS PRESENTATIONS)

1. Have the class divide into groups of 2-4, distribute the *Is It Science?* handout, and make the Science Checklist slide available electronically.

2. Ask groups to select a topic that they have a legitimate question or within-group disagreement about whether that topic/line of investigation is or can be scientific (e.g. astrology, art history, psychotherapy, etc). Students might want to review the ideas they generated in Part 1 of the activity. The group will compare the practices, behaviors, and traits associated with the selected topic/investigation to the *Science Checklist*, and prepare a 5-minute presentation for the class describing the ways in which that topic does and does not align with the features of scientific research. They may use the *Science Checklist* slide if they wish.



Who are Scientists?

Overview

After examining the common stereotype of the lone scientist, students watch **LUMINOUS** and construct a network map of the diverse individuals who contributed to the investigation of variable stars depicted in the film. Students then develop a final project that communicates nuanced views of who does science and how.

TIMING: 1.5-2 hours in class, and 4-6 hours of student work outside of class

OBJECTIVES
Students will:

- Recognize that science is a community endeavor that depends on a diverse group of contributors with a wide array of identities, backgrounds, and roles.
- Examine a common research methodology of assessing stereotypes of scientists.
- Interpret demographic data on scientists employed in different disciplines.

MATERIALS

- *Draw-a-Scientist* assignment
- *Draw-a-Scientist* slides
- *Science Network* assignment
- **LUMINOUS** *Community* Discussion Prompts
- *Scientist Demographics* worksheet and slides

Procedure

PART 01: PRE-VIEWING ASSIGNMENT AND DISCUSSION
(30-55 MINUTES IN CLASS AND 30 MINUTES OUTSIDE OF CLASS)

1. The week before beginning this module, ask students to complete the Draw-a-Scientist assignment. Each student will collect data from two acquaintances and upload photos of the resulting drawings to a shared Google drive.

2. In class, explain that students will be examining common stereotypes of scientists and the scientific community and comparing these to an example of science in action. Give students 5 minutes of solo writing time to list stereotypes of science/scientists that they think are common.

3. Engage the class in a discussion of this writing prompt and keep a running list. Project the drawings they collected and discuss how these embody or reject the stereotypes, continuing to add to the list. Ask the class to identify any stereotypes that they think have a grain of “truth” to them and place an asterisk next to these. You may wish to use the Draw-a-Scientist slides to compare their ideas about stereotypes to findings from social science research. (Instructors will need to photograph or save the list constructed for use in Part 03.)

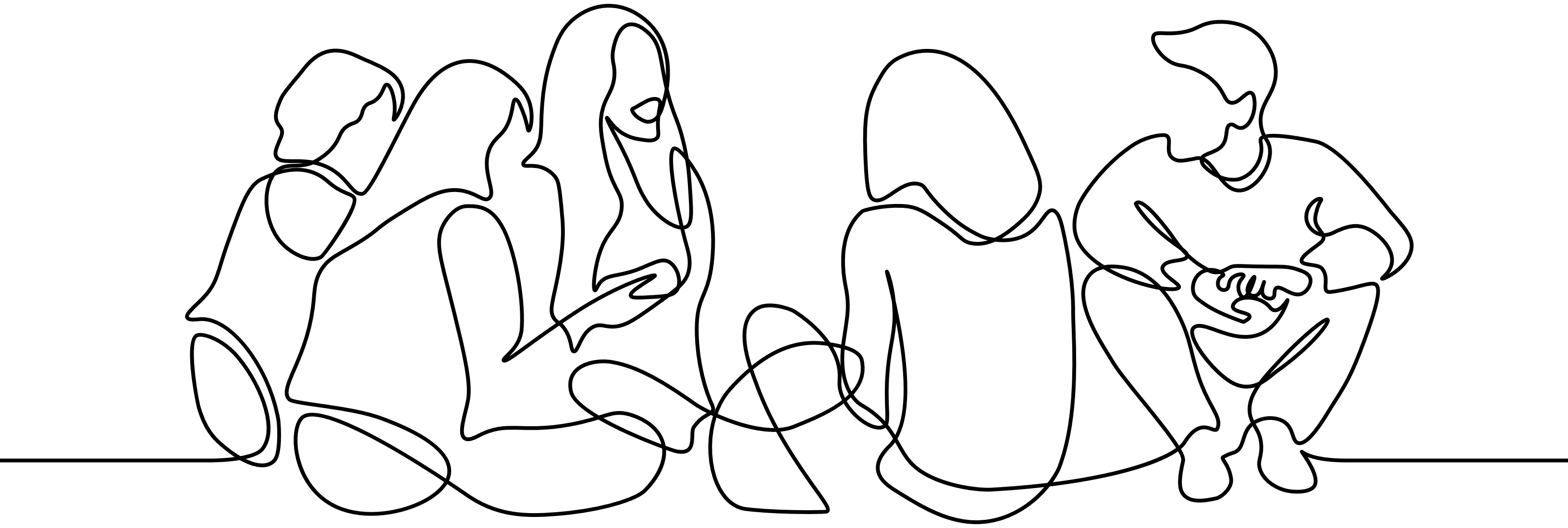
4. Project the last slide in the Draw-a-scientist deck with the “Science Club” cartoon. Ask students what they think the main message of this cartoon is. Have them elaborate on this by comparing the cartoon to the inclusive list of stereotypes and identify the ones that it aims to reject.

PART 02: VIEWING AND NETWORK MAP CONSTRUCTION (~2 HOURS OUTSIDE OF CLASS)

1. Remind students that part of the process of science is engaging with the scientific community, although most responses to the Draw-a-scientist prompt result in images of a single person. In the film **LUMINOUS**, students will observe scientists at work, and observe them interact in various ways with members of their scientific and broader communities.
2. Distribute the Science Network assignment, or share it as a Google doc.
3. Assign students to watch the film **LUMINOUS** (in class or as homework) and construct a visual model of the social network responsible for this investigation of a binary star system and for communicating these results to the public. Each individual or group of people should be represented as a bubble ("node") in the network, and lines and arrows should show interactions and relationships (link to example). For each individual in the network, students will record name, position/job, relation to Dr. Molnar or the project, their motivation for being involved with the investigation, and any aspects of their personal traits or background relevant to the investigation or how they contradict or reinforce stereotypes about scientists. Network maps can be constructed freehand or digitally using the graphic tools available in Microsoft Office or Google Slides or Jamboards.

PART 03: POST-VIEWING DISCUSSION (30-55 MINUTES IN CLASS)

1. Have students divide into groups 3-4 and share or pass around their network maps. Provide each group with access to the list of stereotypes they constructed in Part 1 and the **LUMINOUS** Community Discussion Prompts.
2. Groups should discuss each prompt. You may choose to request written responses.
3. You may wish to use the Scientist Demographics worksheet and slides to discuss the ways in which the diversity of the scientific workforce (in terms of race and gender) has improved and the many ways in which it still does not reflect the diversity of the broader U.S. population. Distribute the worksheet and ask students to spend 10 minutes completing it. You may then use the slides as you solicit students' interpretations of each data visualization. Lead a brief discussion to solicit students' ideas on why the diversity of the scientific workforce lags substantially behind the diversity of the U.S. population. This will likely lead to many more questions. See Additional Resources for more on this topic that you may share with students.
4. Project the last slide in the Draw-a-scientist deck with the "Science Club" cartoon. Ask the class to reflect on the ways that the main messages of the cartoon are captured or not captured by the film they watched. If you used the Scientist demographics activity, ask the class to reflect on the ways that the main messages of the cartoon align and do not align with the data on scientist demographics.



04
Additional Resources

Use these links to learn more about key topics from the film LUMINOUS and to support your teaching with this guide.

Explore the Understanding Science website for more about the nature and process of science, or access information on specific topics relevant to this guide below:

- The dynamic, nonlinear process of science
- The key traits of science
- Science as a community endeavor
- What is a part of the "natural" world?
- Behaviors and ways of thinking that move science forward
- The role of scrutiny in science
- Accords between science and religion/spirituality
- A primer on the philosophy of science

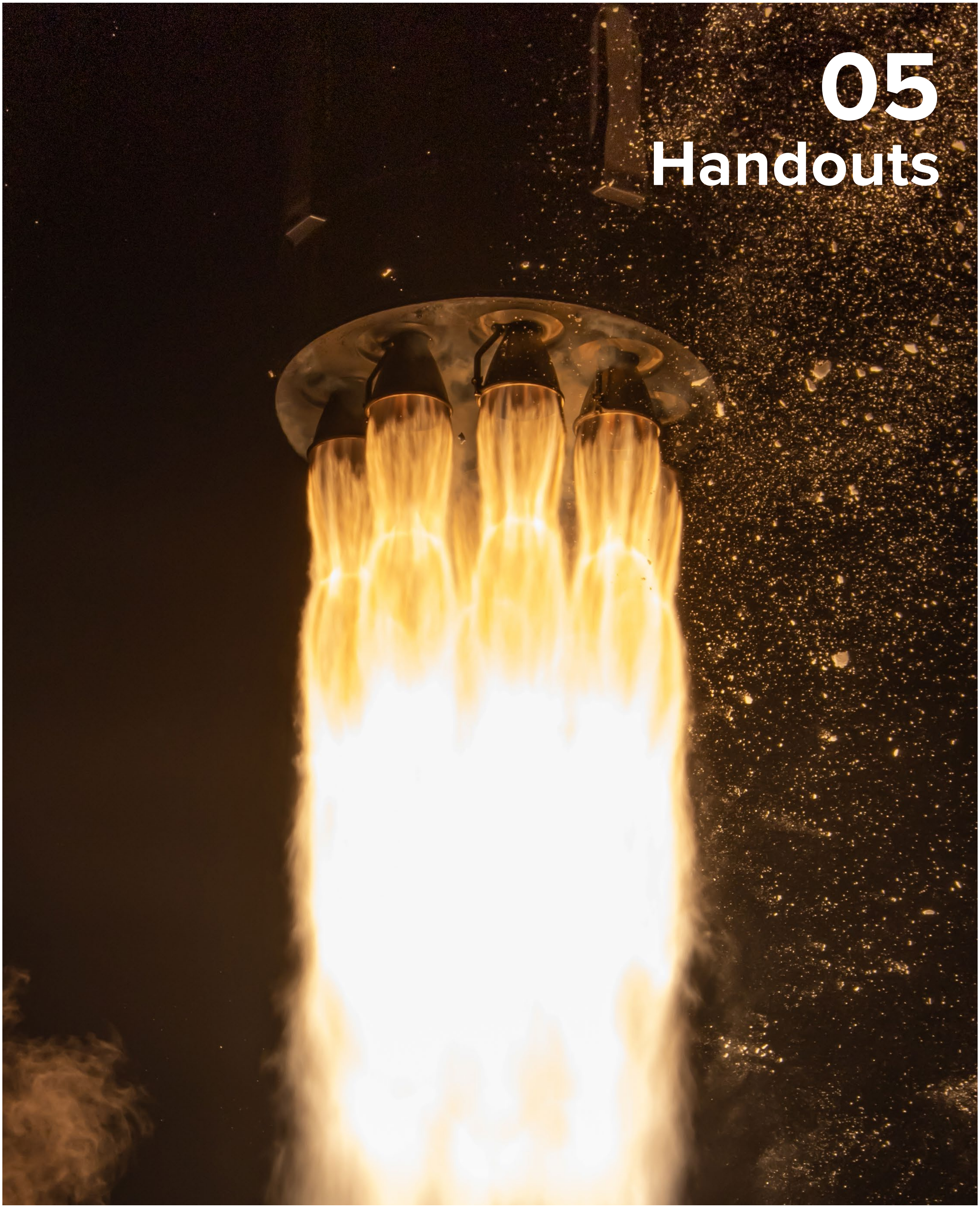
Learn more about teaching the process of science and developing scientific thinking skills in the resources below. Note that current undergraduate education frameworks align with or reference the Science and Engineering Practices from the K-12 Next Generation Science Standards.

- Science and Engineering Practices in the Next Generation Science Standards
- Vision and Change: The Future of Undergraduate Geoscience Education
- Vision and Change in Undergraduate Biology Education

Explore these resources to learn more about diversity and discrimination in science:

- Report on gender, racial, and ethnic diversity in the scientific workforce, from the Pew Research Center
- Report on women, historically marginalized racial groups, and people with disabilities in STEM, from NSF
- A discussion of some of the causes, and means of redressing, lack of diversity in STEM, from Nature
- A summary of issues that influence recruitment and retention of historically marginalized demographic groups, from BioScience
- Article on discrimination in science workplaces, from Nature
- How science benefits from diverse participants, from Understanding Science

05 Handouts



The Science Checklist

The key traits of scientific endeavors are listed below. As you watch the film **LUMINOUS**, use this worksheet to take notes on how the journey of Larry Molnar and colleagues illustrates each aspect of a scientific endeavor. For each item on the Checklist, write 1-3 sentences and use specific examples from the film.

- ☐ **FOCUSES ON THE NATURAL WORLD**

- ☐ **AIMS TO EXPLAIN THE NATURAL WORLD**

- ☐ **USES TESTABLE IDEAS**

- ☐ **RELIES ON EVIDENCE**

- ☐ **INVOLVES THE SCIENTIFIC COMMUNITY**

- ☐ **LEADS TO ONGOING RESEARCH**

- ☐ **BENEFITS FROM SCIENTIFIC BEHAVIOR**

Is It Science?

Timing: 1-2 hours

Your group will select a topic about which you are unsure if (or disagree as to) how scientific it is or could be. Examples of potential topics include astrology and art history. Clear your topic with the instructor. Your group will then conduct library or internet research to compare the practices, behaviors, and traits associated with the selected topic/investigation to the Science Checklist below. You will prepare a 5-minute presentation describing the ways in which that topic does and does not align with the features of scientific research. Be prepared to answer questions from the class!

Topic: ____________________

Due date/presentation date: ____________________

Science Checklist:

HOW SCIENTIFIC IS IT?

- ☐ **FOCUSES ON THE NATURAL WORLD**
- ☐ **AIMS TO EXPLAIN THE NATURAL WORLD**
- ☐ **USES TESTABLE IDEAS**
- ☐ **RELIES ON EVIDENCE**
- ☐ **INVOLVES THE SCIENTIFIC COMMUNITY**
- ☐ **LEADS TO ONGOING RESEARCH**
- ☐ **BENEFITS FROM SCIENTIFIC BEHAVIOR**

Draw-a-Scientist

Timing: 15-30 minutes

The draw-a-scientist task has been used for over 40 years to assess students' stereotypes of scientists. You will administer the task to two friends or acquaintances.

THESE DRAWINGS WERE THREE OF AROUND 5,000 USED IN A DRAW-A-SCIENTIST STUDY (CHAMBERS, 1983). PHOTO CREDIT: WIKIPEDIA.

Provide each of two participants with a blank sheet of paper and drawing implements.

- Give them the following prompt: *"Imagine that tomorrow you are going on a trip (anywhere) to visit a scientist in a place where the scientist is working right now. Draw the scientist busy with the work this scientist does. Add a caption, which tells what this scientist might be saying to you about the work you are watching the scientist do. Do not draw yourself."* [1] They should spend 5-15 minutes on the task. Encourage them to draw whatever springs to mind, and do not elaborate with more specific instructions. Your goal is to get their unfiltered perspective.

- Ask them NOT to write their name on the drawing. We will be viewing and discussing these drawings as a class, and they should remain anonymous.

- Photograph the resulting drawings and upload them as instructed. Title the files with your name.

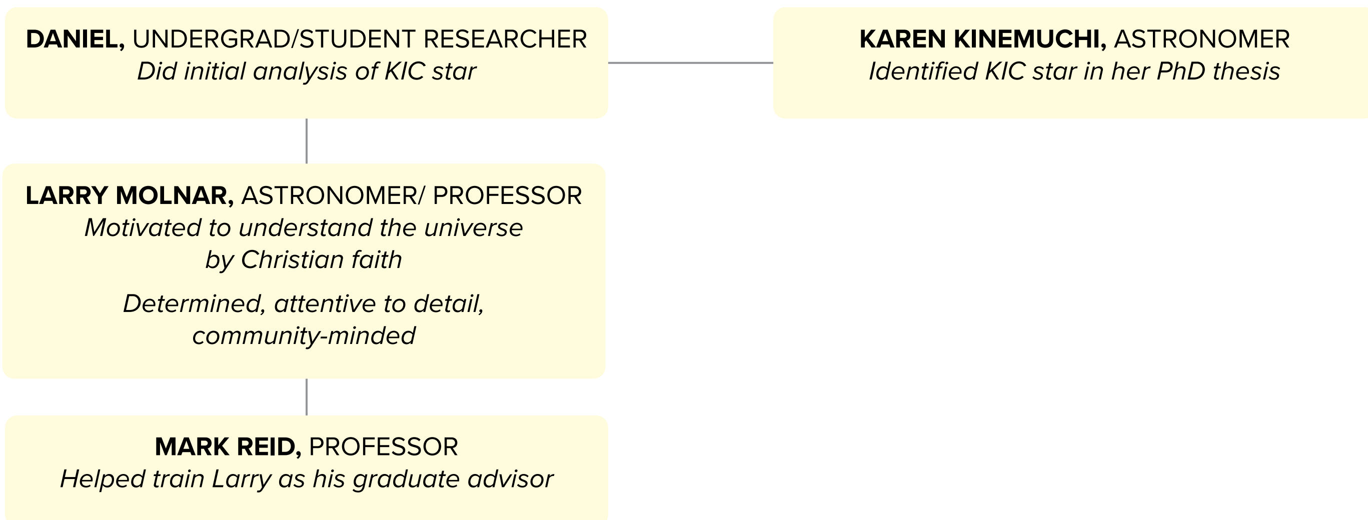
Due date: ______________________________

[1] Prompt modified from Farland-Smith, D. (2012). Development and field test of the modified Draw-A-Scientist Test and the Draw-A-Scientist Rubric. School Science and Mathematics. 112: 109-116.

Science Network

Timing: ~2 hours

As you watch the film **LUMINOUS**, you will construct a visual model of the social network responsible for this investigation of a binary star system and for communicating these results to the public. A small part of a one potential sample network is shown below. Yours may differ.



Provide each of two participants with a blank sheet of paper and drawing implements.

- Represent each individual or group of people as a bubble ("node") in the network. For each node, record if relevant:
  - name
  - position/job
  - relation to Dr. Molnar or contribution the project
  - motivations for being involved with the investigation
  - background/personal traits relevant to the investigation
- Choose a color to highlight elements that don't fit stereotypes of science or scientists.
- Use lines and arrows to show interactions and relationships.
- Network maps can be constructed freehand or digitally using the graphic tools available in Microsoft Office or Google Slides or Jamboard.

Due date: ______________________________

LUMINOUS Community Discussion Prompts

Timing: 1-2 hours

In your small groups, discuss the following questions:

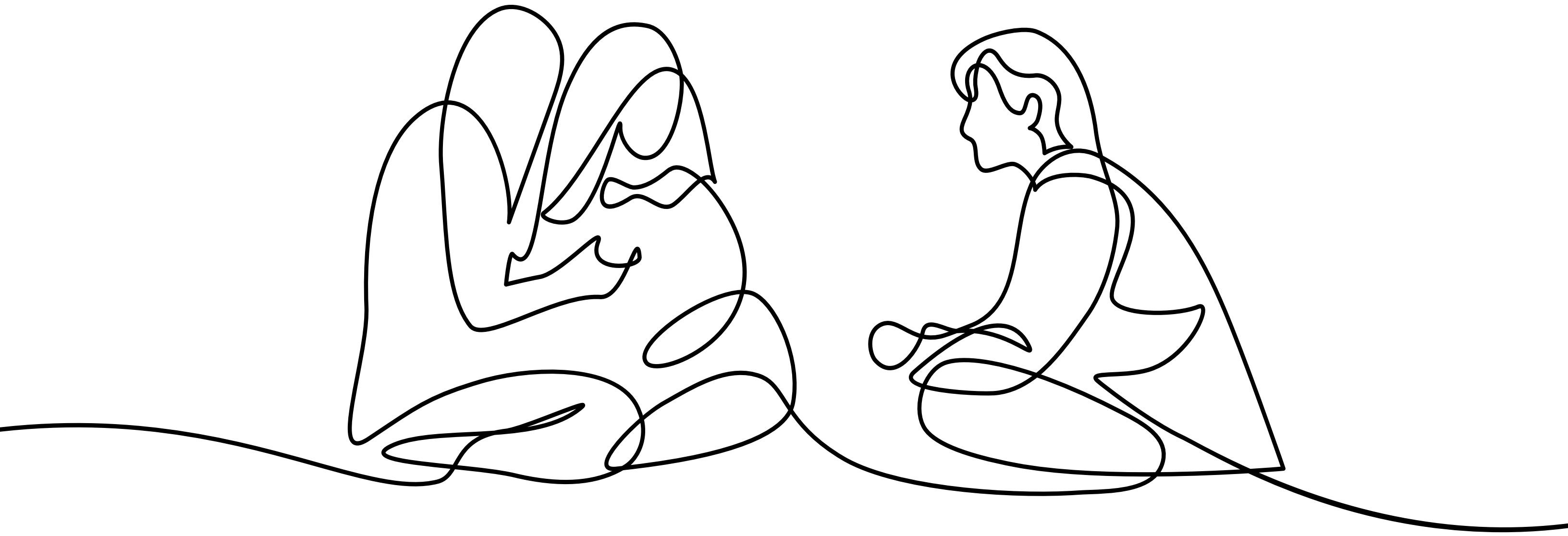
01 What similarities do you notice across the network maps that the people in your group have drawn?

02 What differences do you notice across the network maps that the people in your group have drawn?

03 What overall messages about the process of science do these network maps convey?

04 In what ways do the scientists in the film defy and align with common stereotypes of who scientists are as people? Do not limit your discussion to gender and racial stereotypes.

05 How has your thinking about who scientists are and how science works changed as a result of watching the film and completing this activity



Scientist Demographics

Timing: 10-20 minutes

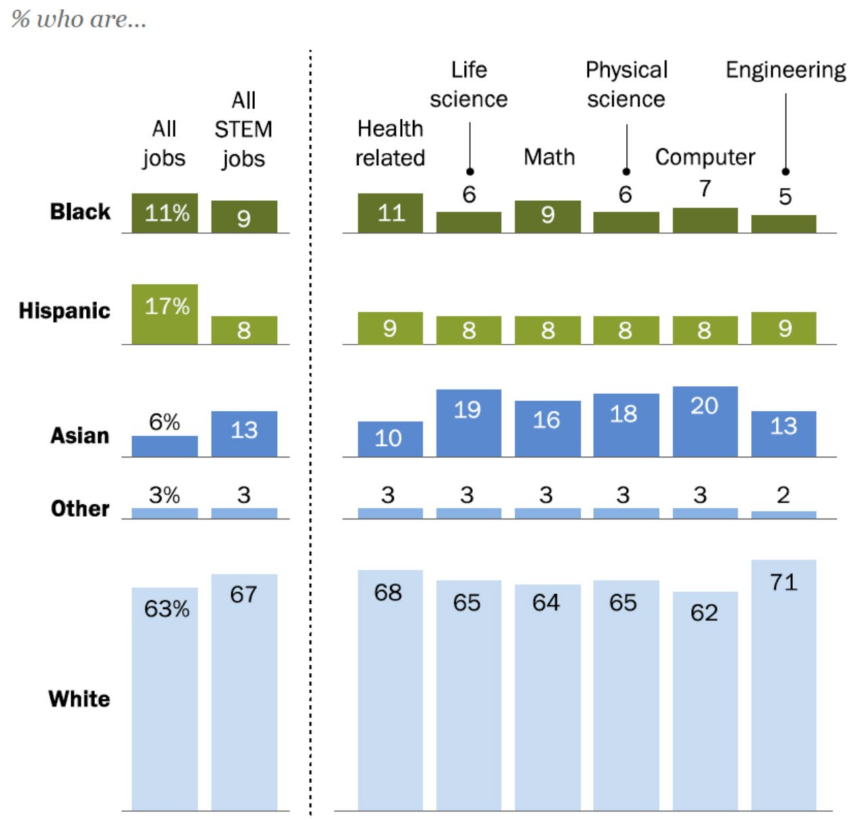
While science should be open to anyone, the reality is that science has been and still can be exclusionary. Answer the data interpretation questions for each diagram.

Which racial groups (several of which were historically marginalized and oppressed) are under- and over-represented in STEM jobs? Describe how the diagram supports this answer.

Which STEM fields have the largest and smallest discrepancies between the racial diversity of their workforces and the racial makeup of the US workforce? Describe how the diagram supports this answer.

What is the most interesting, surprising, important, or meaningful thing that you learned from this data visualization?

STEM EMPLOYMENT IN THE US[1]



Notes: Based on employed adults ages 25 and older. STEM stands for science, technology, engineering and math occupations. Engineering includes architects. White, Black and Asian adults include those who report being only one race and are not Hispanic. Hispanics are of any race. Other includes non-Hispanic American Indian or Alaskan native, non-Hispanic Native Hawaiian or Pacific Islander and non-Hispanic two or more major racial groups.
Source: Pew Research Center analysis of 2017-19 American Community Survey (IPUMS)
"STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity"

PEW RESEARCH CENTER

[1] Graphic from "STEM jobs see uneven progress in increasing gender, racial, and ethnic diversity." Pew Research Center, Washington, D.C. (April 1, 2021)
PEWRESEARCH.ORG/SCIENCE/2021/04/01/STEM-JOBS-SEE-UNEVEN-PROGRESS-IN-INCREASING-GENDER-RACIAL-AND-ETHNIC-DIVERSITY/

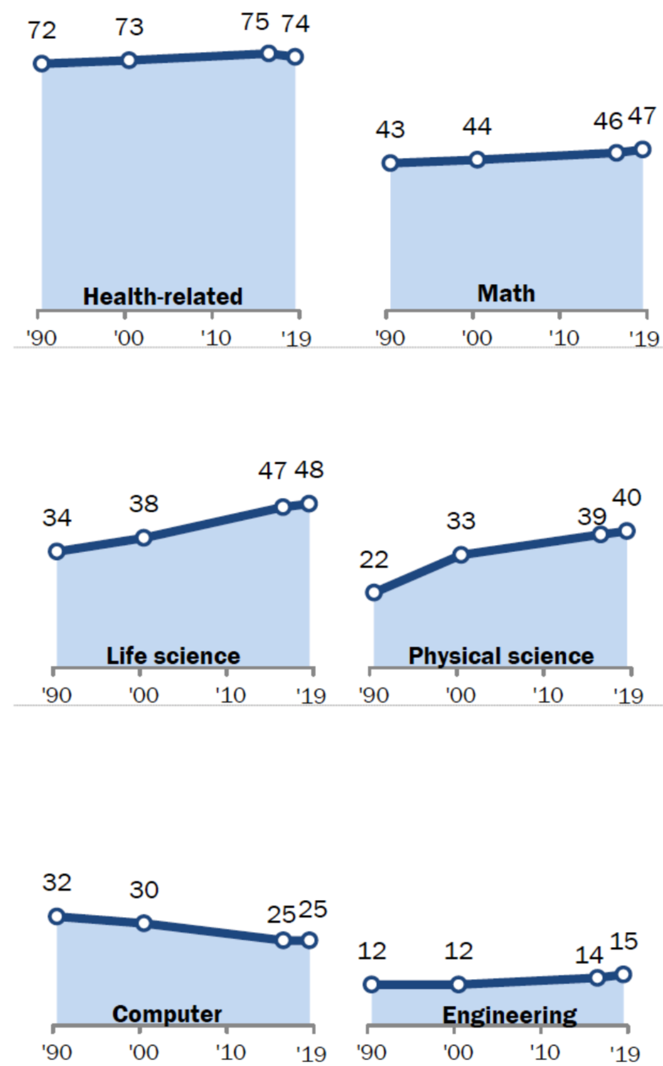
Scientist Demographics (CONTINUED)

In which STEM fields are women most under-represented? Describe how the diagrams support this answer.

Which STEM fields have changed most rapidly in terms of the representation of women for the time period shown? Describe how the diagrams support this answer.

What is the most interesting, surprising, important, or meaningful thing that you learned from this data visualization?

Share of employed in each occupational group who are women (%)[2]



Note: Based on employed adults ages 25 and older. Engineering includes architects.
Source: Pew Research Center analysis of 2017-19 American Community Survey (IPUMS).
"STEM Jobs See Uneven Progress in Increasing Gender, Racial and Ethnic Diversity"

PEW RESEARCH CENTER

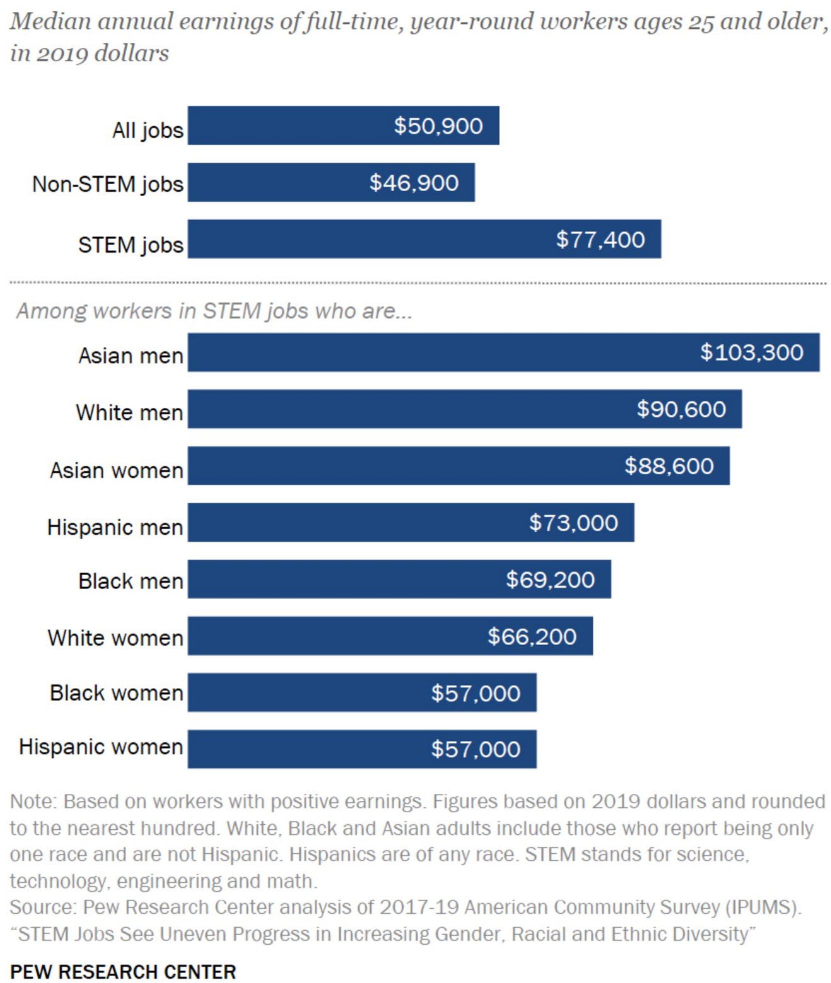
[2] Graphic from "STEM jobs see uneven progress in increasing gender, racial, and ethnic diversity." Pew Research Center, Washington, D.C. (April 1, 2021) PEWRESEARCH.ORG/SCIENCE/2021/04/01/STEM-JOBS-SEE-UNEVEN-PROGRESS-IN-INCREASING-GENDER-RACIAL-AND-ETHNIC-DIVERSITY/

Scientist Demographics (CONTINUED)

How do women fare compared to men in terms of earnings in STEM jobs? Describe how the diagram supports this answer.[3]

How do historically marginalized groups compare to others in terms of earnings in STEM jobs? Describe how the diagram supports this answer.

What is the most interesting, surprising, important, or meaningful thing that you learned from this data visualization?



[3] Graphic from "STEM jobs see uneven progress in increasing gender, racial, and ethnic diversity." Pew Research Center, Washington, D.C. (April 1, 2021) PEWRESEARCH.ORG/SCIENCE/2021/04/01/STEM-JOBS-SEE-UNEVEN-PROGRESS-IN-INCREASING-GENDER-RACIAL-AND-ETHNIC-DIVERSITY/

06 Credits and Acknowledgments

For more information about LUMINOUS and to download educational materials, visit LUMINOUS-FILM.COM

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